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Proprietary Notice
This letter forwards proprietary information in accordance with 10CFR2.390. Upon the removal of Enclosure 1, the balance of this letter may be considered non-proprietary.

MFN 08-708

Docket No. 52-010

September 22, 2008

U.S. Nuclear Regulatory Commission

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Subject: Response to Portion of NRC Request for Additional Information Letter No. 161 – Related to ESBWR Design Certification Application – RAI Number 21.6-113

The purpose of this letter is to submit the GE Hitachi Nuclear Energy (GEH) response to the U.S. Nuclear Regulatory Commission (NRC) Request for Additional Information (RAI) sent by the Reference 1 NRC letter. GEH response to RAI Number 21.6-113 is addressed in Enclosures 1, 2 and 3.

Enclosure 1 contains GEH proprietary information as defined by 10 CFR 2.390. GEH customarily maintains this information in confidence and withholds it from public disclosure. Enclosure 2 is the non-proprietary version, which does not contain proprietary information and is suitable for public disclosure.

The affidavit contained in Enclosure 3 identifies that the information contained in Enclosure 1 has been handled and classified as proprietary to GEH. GEH hereby requests that the information in Enclosure 1 be withheld from public disclosure in accordance with the provisions of 10 CFR 2.390 and 10 CFR 9.17.

If you have any questions or require additional information, please contact me.

Sincerely,

Richard E. Kingston

Richard E. Kingston
Vice President, ESBWR Licensing

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NRO

References:

1. MFN 08-228 Letter from U.S. Nuclear Regulatory Commission to David H. Hinds, GEH, *Request For Additional Information Letter No. 161 Related To ESBWR Design Certification Application*, dated March 7, 2008.

Enclosures:

1. MFN 08-708 – Response to Portion of NRC Request for Additional Information Letter No. 161 – Related to ESBWR Design Certification Application – RAI Number 21.6-113 – GEH Proprietary Information
2. MFN 08-708 – Response to Portion of NRC Request for Additional Information Letter No. 161 – Related to ESBWR Design Certification Application – RAI Number 21.6-113 – Non-Proprietary Version
3. MFN 08-708 – Response to Portion of NRC Request for Additional Information Letter No. 161 – Related to ESBWR Design Certification Application – RAI Number 21.6-113 – Affidavit

cc:	AE Cubbage	USNRC (with enclosure)
	RE Brown	GEH/Wilmington (with enclosure)
	DH Hinds	GEH/Wilmington (with enclosure)
	eDRF	0000-0090-0450

Enclosure 2

MFN 08-708

Response to Portion of NRC Request for

Additional Information Letter No. 161

Related to ESBWR Design Certification Application

RAI Number 21.6-113

Non-Proprietary Version

NRC RAI 21.6-113

How would the TRACG nodalization and flow-regime maps in the chimney capture the phenomenon of non-fully developed flow at the inlet?

In the ESBWR, the flow from 16 fuel bundles and their associated bypass region join into a single chimney channel. Due to mixing and three-dimensional effects, the flow at the chimney channel inlet will not be fully developed and may transition between separated flow regimes; however, TRACG models assume instantaneous mixing and flow-regime maps.

A. How would the TRACG nodalization and flow-regime maps in the chimney capture the phenomenon of non-fully-developed flow at the inlet?

B. What experimental evidence exists that the non-fully-developed flow at the chimney inlet does not cause core flow fluctuations that could be a concern for safe ESBWR operation?

C. If the experimental evidence is not for full power/flow/pressure conditions, provide a scaling analysis to support the above conclusions.

GEH Response

A. The TRACG nodalization and flow regime map are not intended to capture the full detail of flow development at the inlet to the chimney. TRACG is not a Computational Fluid Dynamics (CFD) code and does not treat the details of turbulent mixing in two-phase flows. A more detailed axial and radial nodalization could be used, but this will not satisfactorily resolve the fine structure of the flow within the chimney cell. The flow regime map in TRACG is based on quasi-static, fully developed conditions. It does not account for a developing region at the inlet. These limitations in TRACG do not impact its application for ESBWR analysis. The adequacy of TRACG for ESBWR analysis is justified on the grounds that phenomena related to chimney entrance effects are not important for safe ESBWR operation. This justification is provided below.

Non-fully developed flow in the entrance region could potentially have two effects:

1.The void fraction in this region could be lower than in fully developed flow.

2. Unsteady effects (periodic fluctuations) in velocity and void fraction could be introduced.

Both of these effects could influence the core flow response. Arguments are developed in this response to show that neither of these effects result in safety-significant impacts.

The void fraction in the entrance region is addressed by experimental data in Part B of this response. The length of the entrance region is shown to be small relative to the chimney height such that the effect on the calculated chimney static head and natural circulation flow is small.

TRACG cannot accurately calculate unsteady phenomena due to vortex shedding and periodic void fluctuations in the churn turbulent flow regime. However, potential periodic flow disturbances in the chimney are significantly damped in the core flow response.

Physical arguments can be made as to why the core flow is not sensitive to perturbations in the chimney. The natural frequencies of the chimney for loop flow oscillations (~0.1 Hz) and for density waves in the core (~ 1Hz) are very different. Disturbances in the chimney at frequencies close to 0.1 Hz are quasi-static with respect to the core dynamics, and nuclear feedback tends to maintain a constant void fraction in the core to keep the core critical. On the other hand, frequencies close to the core density wave frequency of 1Hz occupy several wavelengths in the chimney. Hence, these perturbations create only small changes in the total chimney static head as they travel through the chimney. Frictional losses in the chimney are insignificant. Hence the impact on core flow is minimal. Frequencies in the intermediate range are not close to the natural frequency in either the core or the chimney.

B. Experimental evidence: The ESBWR chimney is a partitioned structure, consisting primarily of vertical cells of a square cross-section (0.61 m X 0.61 m). Each chimney cell is fed by the outflows from 16 fuel bundles and the associated bypass region. The average mass flux in the chimney is [[ ]]. The void fraction ranges from [[ ]] in the peripheral chimney to [[ ]] in the central region.

The Dodewaard plant had a similar configuration in the chimney, though with a smaller chimney cell (0.3 m vs. 0.61 m), and flow from four bundles and the associated bypass region feeding the chimney cell. The operating pressure of 75.5 bar was similar to ESBWR. The plant operated with a typical average chimney void fraction of 0.50 and average chimney mass fluxes in the range of 370 kg/m^2-s, as obtained from Reference [1]. At these conditions, a churn turbulent flow regime would be expected in the chimney (void fraction greater than 0.3 and less than that for transition to annular flow; low vapor velocities). The plant operated without problems for 29 cycles and there were no reported instances of excessive noise in the core resulting from unsteady phenomena in the chimney.

Tests were conducted by Dubrovskii (1974) [2], which examined the developing flow at the inlet to a large diameter riser. This reference is attached to the response.

Measurements of void fraction were made at various elevations in a core riser 0.6 m in diameter and 3 m high. The circulation loop consisted of a 'bubbler', a core riser, overflow outlets and a downcomer channel. The 'bubbler' was a cylindrical shell with two tube lattices into which 37 tubes were vertically inserted. The pitch of these assemblies was 85 mm and the outlet diameter was 61 mm. The bubbler was designed to enable a nonuniform distribution of steam flow to individual groups of assemblies. In the six assemblies of Group 5, positioned at the apexes of the hexahedron lattice, the relative steam load could be varied over a range of 0 to 0.2.

Saturated or slightly superheated steam was supplied to the space between the assemblies and distributed into the flow of circulating water through holes in the side surfaces of the assemblies. The steam distribution among these assemblies was governed by the flow areas of these holes. In the assemblies in Group 5, a controlled amount of steam was directly supplied to the tubes, which had no perforations. (The data shown in the paper are for the case where no steam was introduced into the Group 5 assemblies.) The two-phase flow formed in the assemblies flowed into the core riser, with a nonuniform distribution of steam content. Water and some carryunder steam flowed back into the downcomer where the steam was condensed by the feedwater flow. A heat exchanger was also located in the downcomer to subcool the flow in the downcomer. Tests were conducted over a pressure range of 30 to 100 bar, and riser superficial velocities of 0.08 to 1.0 m/s for steam and 0.18 to 0.32 m/s for water. At the pressure of 75 bar, the steam velocity ranged from 0.06 to 0.51 m/s and water velocity from 0.23 to 0.32 m/s. Typical mass fluxes were of the order of 210 kg/m^2-s and void fractions in the range of 0.4 to 0.5.

Void fraction measurements were made at elevations of 150 mm, 1500 mm, 2000 mm and 2500 mm above the bottom of the core riser. The void fraction was evaluated from narrow gamma-ray attenuation measurements using eight Co-60 and Cs-137 sources. Void fraction for vertical segments of the chimney and downcomer were also calculated from static pressure measurements along the height.

Results showed that the void fraction distribution across the cross-section was non-uniform, with higher steam content above the regions of highest steam injection. As the distance above the bubbler increased, the void distribution became more uniform. In the region directly above the bubbler, the average void fraction increased due to the mixing of the two-phase streams to an asymptotic value corresponding to that for fully developed flow. The length of the initial developing region was not determined accurately (because of the distance between measuring stations) but was established to be less than 2.2 diameters (1.3 m). In the initial developing region, at a height of 0.24 diameters, the average void fraction was about 75% of the fully developed value. Other data are quoted for a similar configuration with a riser diameter of 0.748 m. The developing region was determined to be less than one diameter (0.75 m). These experimental observations support the assertion that a fully developed churn turbulent regime develops in the first meter of the chimney height. The void fraction in this first meter is slightly lower (by less than 25%) of the fully developed value.

The void fraction increases continuously in the entrance region from a value about 75% of the fully developed value just above the inlet (0.24 D) to the fully developed value at the end of the entrance region (~ 1m). Assuming a linear increase in the void fraction from the inlet in the first meter and a fully developed value of 0.7, the error in the static head for the 7 m high ESBWR chimney at rated operating conditions is of the order of 3% if the fully developed value is used for the entire length.

The data showed that the nonuniformity in the void distribution persisted up the length, and resolved gradually, but the average void fraction was not affected, and remained constant above the initial developing length. The constant flow velocity in the downcomer indicated stable flow in the core riser, with no noticeable oscillations. Entrance effects that were present in the test did not result in oscillatory behavior. While the data shown in the paper are mainly at a pressure of 100 bar, the conclusions are stated to be applicable to the entire range of investigated pressures and steam loads.

C. Scaling:

For all three cases – ESBWR, Dodewaard and the Dubrovskii test - the steam velocities are too low to result in annular flow; consequently, the flow regime is churn turbulent flow.

The Dodewaard chimney operated at a similar pressure to the ESBWR and at a similar mass flux. The physical size of the chimney cell was half of the ESBWR chimney cell. The void fraction in the chimney was 0.5, putting it clearly in the churn turbulent flow regime.

The Dubrovskii data cover the rated pressure (75 bar) for ESBWR operation and are for a similar hydraulic diameter (0.61m) section as an ESBWR chimney cell. An extreme case for an ESBWR peripheral chimney cell shows a variation in individual bundle steam flows ranging from 0.47 to 1.49 times the average value. In the Dubrovskii test the non-uniform distribution of inlet steam flow spans the range from 0 to 1.92 times the average value, which covers the variation between assemblies within a chimney cell. The steam and water velocities are lower than for the ESBWR chimney. The entrance length L/D decreases with increasing Reynolds number. At ESBWR Reynolds numbers, the flow is more turbulent and the entrance region should be even smaller than in the tests.

DCD Impact

No DCD changes will be made in response to this RAI.

References

1. TRACG Qualification for SBWR, MFN # 02-053, NEDC-32725P, Vol. 2, Table 6.1-1, 6.1-3, August 30, 2002.

2. Dubrovskii, I. S., *Hydrodynamics of Adiabatic Two-Phase Flow in Large Core Risers,* Teploenergetika, **21** (2), pp. 31-35, 1974.

Enclosure 3

MFN 08-708

Response to Portion of NRC Request for

Additional Information Letter No. 161

Related to ESBWR Design Certification Application

RAI Number 21.6-113

Affidavit

GE-Hitachi Nuclear Energy Americas LLC

AFFIDAVIT

I, David H. Hinds, state as follows:

(1) I am General Manager, New Units Engineering, GE Hitachi Nuclear Energy ("GEH"), and have been delegated the function of reviewing the information described in paragraph (2) which is sought to be withheld, and have been authorized to apply for its withholding.

(2) The information sought to be withheld is contained in enclosure 1 of GEH's letter, MFN 08-708, Mr. Richard E. Kingston to U.S. Nuclear Energy Commission, entitled "*Response to Portion of NRC Request for Additional Information Letter No. 161 – Related to ESBWR Design Certification Application – RAI Number 21.6-113,*" dated September 22, 2008. The proprietary information in enclosure 1, which is entitled "*MFN 08-708 – Response to Portion of NRC Request for Additional Information Letter No. 161 – Related to ESBWR Design Certification Application – RAI Number 21.6-113 – GEH Proprietary Information,*" is delineated by a [[dotted underline inside double square brackets{3}]]. Figures and large equation objects are identified with double square brackets before and after the object. In each case, the superscript notation {3} refers to Paragraph (3) of this affidavit, which provides the basis for the proprietary determination.

(3) In making this application for withholding of proprietary information of which it is the owner or licensee, GEH relies upon the exemption from disclosure set forth in the Freedom of Information Act ("FOIA"), 5 USC Sec. 552(b)(4), and the Trade Secrets Act, 18 USC Sec. 1905, and NRC regulations 10 CFR 9.17(a)(4), and 2.390(a)(4) for "trade secrets" (Exemption 4). The material for which exemption from disclosure is here sought also qualify under the narrower definition of "trade secret", within the meanings assigned to those terms for purposes of FOIA Exemption 4 in, respectively, Critical Mass Energy Project v. Nuclear Regulatory Commission, 975F2d871 (DC Cir. 1992), and Public Citizen Health Research Group v. FDA, 704F2d1280 (DC Cir. 1983).

(4) Some examples of categories of information which fit into the definition of proprietary information are:

a. Information that discloses a process, method, or apparatus, including supporting data and analyses, where prevention of its use by GEH's competitors without license from GEH constitutes a competitive economic advantage over other companies;

b. Information which, if used by a competitor, would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing of a similar product;

c. Information which reveals aspects of past, present, or future GEH customer-funded development plans and programs, resulting in potential products to GEH;

d. Information which discloses patentable subject matter for which it may be desirable to obtain patent protection.

The information sought to be withheld is considered to be proprietary for the reasons set forth in paragraphs (4)a. and (4)b. above.

(5) To address 10 CFR 2.390(b)(4), the information sought to be withheld is being submitted to NRC in confidence. The information is of a sort customarily held in confidence by GEH, and is in fact so held. The information sought to be withheld has, to the best of my knowledge and belief, consistently been held in confidence by GEH, no public disclosure has been made, and it is not available in public sources. All disclosures to third parties, including any required transmittals to NRC, have been made, or must be made, pursuant to regulatory provisions or proprietary agreements which provide for maintenance of the information in confidence. Its initial designation as proprietary information, and the subsequent steps taken to prevent its unauthorized disclosure, are as set forth in paragraphs (6) and (7) following.

(6) Initial approval of proprietary treatment of a document is made by the manager of the originating component, the person most likely to be acquainted with the value and sensitivity of the information in relation to industry knowledge, or subject to the terms under which it was licensed to GEH. Access to such documents within GEH is limited on a "need to know" basis.

(7) The procedure for approval of external release of such a document typically requires review by the staff manager, project manager, principal scientist, or other equivalent authority for technical content, competitive effect, and determination of the accuracy of the proprietary designation. Disclosures outside GEH are limited to regulatory bodies, customers, and potential customers, and their agents, suppliers, and licensees, and others with a legitimate need for the information, and then only in accordance with appropriate regulatory provisions or proprietary agreements.

(8) The information identified in paragraph (2) above is classified as proprietary because it contains details of GEH's evaluation methodology.

The development of the evaluation process along with the interpretation and application of the analytical results is derived from the extensive experience database that constitutes a major GEH asset.

(9) Public disclosure of the information sought to be withheld is likely to cause substantial harm to GEH's competitive position and foreclose or reduce the availability of profit-making opportunities. The information is part of GEH's comprehensive BWR safety and technology base, and its commercial value extends beyond the original development cost. The value of the technology base

goes beyond the extensive physical database and analytical methodology and includes development of the expertise to determine and apply the appropriate evaluation process. In addition, the technology base includes the value derived from providing analyses done with NRC-approved methods.

The research, development, engineering, analytical and NRC review costs comprise a substantial investment of time and money by GEH.

The precise value of the expertise to devise an evaluation process and apply the correct analytical methodology is difficult to quantify, but it clearly is substantial.

GEH's competitive advantage will be lost if its competitors are able to use the results of the GEH experience to normalize or verify their own process or if they are able to claim an equivalent understanding by demonstrating that they can arrive at the same or similar conclusions.

The value of this information to GEH would be lost if the information were disclosed to the public. Making such information available to competitors without their having been required to undertake a similar expenditure of resources would unfairly provide competitors with a windfall, and deprive GEH of the opportunity to exercise its competitive advantage to seek an adequate return on its large investment in developing and obtaining these very valuable analytical tools.

I declare under penalty of perjury that the foregoing affidavit and the matters stated therein are true and correct to the best of my knowledge, information, and belief.

Executed on this 22nd day of September 2008.

David H. Hinds
GE-Hitachi Nuclear Energy Americas LLC